U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science Directorate
Geologic Resources Division

Bryce Canyon National Park

GRI Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic Data for Bryce Canyon National Park

brca_geology.pdf

Version: 12/11/2013

Geologic Resources Inventory Map Document for Bryce Canyon National Park

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Geologic Resources Inventory Map Document

Bryce Canyon National Park, Utah

Geologic Database to Accompany Digital Geologic-GIS Data

brca_geology.pdf

Version: 12/11/2013

This digital database has been developed to accompany numerous published and/or unpublished geologic maps in the area of Bryce Canyon National Park, Utah (BRCA)

Attempts have been made to reproduce all aspects of the original source "paper" published product, including the geologic units and their descriptions, geologic cross sections, the geologic report, references, and all other pertinent images and information contained in the original publication.

National Park Service (NPS) Geologic Resources Inventory (GRI) Program staff have assembled the digital geologic-GIS data that accompanies this database.

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About the NPS Geologic Resources Inventory Program

Background

Recognizing the interrelationships between the physical (geology, air, and water) and biological (plants and animals) components of the Earth is vital to understanding, managing, and protecting natural resources. The Geologic Resources Inventory (GRI) helps make this connection by providing information on the role of geology and geologic resource management in parks.

Geologic resources for management consideration include both the processes that act upon the Earth and the features formed as a result of these processes. Geologic processes include: erosion and sedimentation; seismic, volcanic, and geothermal activity; glaciation, rockfalls, landslides, and shoreline change. Geologic features include mountains, canyons, natural arches and bridges, minerals, rocks, fossils, cave and karst systems, beaches, dunes, glaciers, volcanoes, and faults.

The Geologic Resources Inventory aims to raise awareness of geology and the role it plays in the environment, and to provide natural resource managers and staff, park planners, interpreters, researchers, and other NPS personnel with information that can help them make informed management decisions.

The GRI team, working closely with the Colorado State University (CSU) Department of Geosciences and a variety of other partners, provides more than 270 parks with a geologic scoping meeting, digital geologic-GIS map data, and a park-specific geologic report.

Products

Scoping Meetings: These park-specific meetings bring together local geologic experts and park staff to inventory and review available geologic data and discuss geologic resource management issues. A summary document is prepared for each meeting that identifies a plan to provide digital map data for the park.

Digital Geologic Maps: Digital geologic maps reproduce all aspects of traditional paper maps, including notes, legend, and cross sections. Bedrock, surficial, and special purpose maps such as coastal or geologic hazard maps may be used by the GRI to create digital Geographic Information Systems (GIS) data and meet park needs. These digital GIS data allow geologic information to be easily viewed and analyzed in conjunction with a wide range of other resource management information data.

For detailed information regarding GIS parameters such as data attribute field definitions, attribute field codes, value definitions, and rules that govern relationships found in the data, refer to the NPS Geology-GIS Data Model document available at: http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm)

Geologic Reports: Park-specific geologic reports identify geologic resource management issues as well as features and processes that are important to park ecosystems. In addition, these reports present a brief geologic history of the park and address specific properties of geologic units present in the park.

For a complete listing of Geologic Resource Inventory products and direct links to the download site visit the GRI publications webpage http://www.nature.nps.gov/geology/inventory/gre_publications.cfm

Digital geologic-GIS data in these WinZip files and all other digital geologic-GIS data prepared as products of the GRI program are available to download from the NPS Natural Resource Information Reference Search Application: http://nrinfo.nps.gov/Reference.mvc/Search. To find GRI data for a specific park or parks select the appropriate park(s), enter "GRI" as a Search Text term, and then select the Search Button.

For more information about the Geologic Resources Inventory Program visit the GRI webpage: http://www.nature.nps.gov/geology/inventory, or contact:

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The Geologic Resources Inventory (GRI) program is funded by the National Park Service (NPS) Inventory and Monitoring (I&M) program. For more information on the Inventory and Monitoring (I&M) program visit: http://science.nature.nps.gov/im/index.cfm

For more information on this and other Inventory and Monitoring (I&M) Natural Resource inventories visit: http://science.nature.nps.gov/im/inventory/index.cfm

Map Unit List

The geologic units present in source map used for Bryce Canyon National Park, Utah (BRCA) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qa; - Alluvium). Units are generally listed from youngest to oldest. No description for water is provided. Information about each geologic unit is also presented in the Geologic Unit Information (UNIT) table included with the GRI geology-GIS data.

Geologic Map Units

CENOZOIC ERA

Quaternary Period
Qal - Alluvium (Qal)
Qc - Colluvium (Qc)
Qls - Landslide Deposits (Qls)
Qoac - Older alluvium and colluvium (Qoac)
Qp - Pediment Deposits (Qp)

Quaternary-Tertiary Periods
QTsr - Sevier River Formation (QTsr)

Tertiary Period
Tbm - Conglomerate at Boat Mesa (Tbm)
Tcw - Claron Formation, white limestone member (Tcw)
Tcp - Claron Formation, pink limestone member (Tcp)

MESOZOIC ERA

Cretaceous Period
Kk - Kaiparowitz Formation (Kk)
Kw - Wahweep (Kw)
Ksu - Straight Cliffs Formation, upper part (Ksu)
Ksl - Straight Cliffs Formation, lower part (Ksl)
Kt - Tropic Shale (Kt)
Kd - Dakota Formation (Kd)

Jurassic Period
Je - Entrada Sandstone (Je)
Jcu - Carmel Formation, upper member (Jcu)
Jcul - Carmel Formation, limestone marker bed (Jcul)
Jcgt - Carmel Formation, gypsiferous member and (Thousand Pockets Tongue) of Page Ss (Jcgt)
Jcb - Carmel Formation, banded member (Jcb)
Jcl - Carmel Formation, limestone member (Jcl)

Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below.

Qal - Alluvium (Holocene)

Clay, silt, sand, and gravel. Includes some colluvium and slopewash, and coarse poorly sorted flash flood deposits in narrow canyons. Thickness 0-40 ft. (I-2108)

Qc - Colluvium (Holocene and Pleistocene)

Slopewash or mass wasting debris derived from adjacent bedrock or older surficial deposits. Includes some talus and slump deposits beneath steeper slopes. Thickness 0-30 ft. (I-2108)

Qls - Landslide deposits (Holocene and Pleistocene)

Slide or slump debris derived from adjacent bedrock. On Horse Mountain consists of slides or mudflows derived from Tropic Shale; northwest of town of Tropic consists mostly of slide or slump blocks derived from Straight Cliffs Formation. Thickness 0-100 ft. (I-2108)

Qoac - Older alluvium and colluvium (Holocene and Pleistocene)

Older alluvium and colluvium in northern part of map area. Includes gravels of East Fork Sevier River and sediments of mixed origin. Consists mostly of limestone clasts derived from Claron Formation; in extreme northwest corner of map area includes volcanic clasts derived from southern Sevier Plateau. Thickness 0-60 ft. (I-2108)

Qp - Pediment deposits (Pleistocene)

Sand and gravel occurring as remnants of formerly extensive pediment deposits, and lesser amounts of alluvial fan deposits. Coarser clasts are predominantly subrounded to subangular limestone pebbles or cobbles in a sandy calcareous matrix; may contain as much as 20 percent clasts of well-rounded chert and quartzite. Includes some terrace deposits along major drainage channels. May include deposits of Pliocene age. Thickness 0-100 ft. (I-2108)

QTsr - Sevier River Formation (Pleistocene and Pliocene)

Tan to light gray, moderately sorted conglomeratic sandstone and conglomerate. Contains subrounded to subangular clasts of volcanic rocks and angular limestone fragments in a calcareous sandstone matrix; includes volcanic clasts as much as 8 in. in diameter, probably derived from southern Sevier Plateau. Thickness 0-80 ft. (I-2108)

Tbm - Conglomerate at Boat Mesa (Oligocene)

Light brown, tan, and gray calcareous sandstone and conglomeratic sandstone, and light gray to white limestone and conglomeratic limestone. Coarser clasts consist of pebbles of black, gray, and tan chert, and tan quartzite. Thickness 0-100 ft. (I-2108)

Tcw - Claron Formation, white limestone member (middle to lower Eocene)

White, light gray, or tan, fine grained to microcrystalline, cliff forming limestone. Generally thick bedded to massive with indistinct bedding, but locally thin bedded with purplish gray mudstone interbeds. Forms resistant caprock on highest parts of Paunsaugunt Plateau. Elsewhere includes rocks of Oligocene age. Thickness 0-300 ft. (I-2108)

Tcp - Claron Formation, pink limestone member (middle to lower Eocene)

Pale pink, red, pale orange, and tan, very fine grained, thin to thick bedded limestone, argillaceous limestone, and dolomitic limestone with sparse thin interbeds of gray or tan calcareous mudstone. A basal conglomerate 0-40 ft thick occurs locally and consists of varicolored pebbles and cobbles of quartzite, chert, and lesser amounts of limestone. Forms fluted cliffs, columns, hoodoos, and spires, as well as steep slopes, all created by weathering and differential erosion of interbedded harder and softer layers. Much of the spectacular badlands of Bryce Canyon National Park are carved from these beds. Thickness 400-700 ft. (I-2108)

Kk - Kaiparowitz Formation (Upper Cretaceous)

Light brown, tan, and greenish gray, very fine grained, friable sandstone, and buff, fine grained, moderately resistant, lenticular sandstone and interbedded light gray to purplish gray or tan mudstone. Formation mostly removed from Paunsaugunt Plateau by pre Claron erosion. Present only west of Buck Knoll in western part of map area where basal part of unit is exposed. Thickness 0-100 ft. (I-2108)

Kw - Wahweep Formation (Upper Cretaceous)

Upper 50-100 ft consists of light gray to white, fine to coarse grained, crossbedded sandstone and conglomeratic sandstone containing small pebbles of gray chert and tan quartzite. Lower 600 ft is buff to light brown, hard, fine grained, lenticular sandstone interbedded with gray to tan mudstone, thin beds of light gray or white siltstone, and very fine grained sandstone. Thickness 0-700 ft. (I-2108)

Ksu - Straight Cliffs Formation, upper part (Upper Cretaceous)

Upper 100-200 ft consists of white, thick-bedded to massive, medium- to coarse-grained, crossbedded sandstone containing lenses of pebble conglomerate; forms steep slopes or sandy gravel covered benches. Lower 800-1,100 ft is buff, tan, and light brown, very fine grained to fine grained sandstone and interbedded gray to tan mudstone. A 30 ft interval of carbonaceous shale and thin coal about 100 ft above the base is probably equivalent to the Henderson coal zone (Robison, 1966) farther east. Unit is equivalent to the Drip Tank and John Henry Members (Peterson, 1969b) in the Kaiparowits Plateau. Thickness 900-1,300 ft. (I-2108)

Ksl - Straight Cliffs Formation, lower part (Upper Cretaceous)

Upper 80-100 ft is white to light gray, fine- to medium grained, crossbedded sandstone containing lenses of conglomeratic sandstone or pebble conglomerate. Middle 200-250 ft is buff and tan, fine-grained, lenticular sandstone with interbedded tan to gray mudstone, carbonaceous mudstone, and local thin coal beds. Lower 40-50 ft is buff to light brown, very fine grained, flat bedded to low angle crossbedded, cliff forming marine sandstone. Unit is equivalent to the Smoky Hollow and Tibbet Canyon Members (Peterson, 1969b) in the Kaiparowits Plateau. Thickness 320-400 ft. (I-2108)

Kt - Tropic Shale (Upper Cretaceous)

Gray to olive gray marine shale. Includes thin, very fine grained sandstone beds in upper part. Lower part contains very thin beds of tan bentonitic clay and a basal limestone concretion zone, which may contain marine fossils. Thickness 700-1,000 ft. (I-2108)

Kd - Dakota Formation (Upper Cretaceous)

Interbedded buff to light brown sandstone, gray to tan mudstone, dark carbonaceous mudstone, and coal. Basal sandstone is gray to light brown, medium to coarse grained or conglomeratic. Some pebble cobble conglomerate is present locally. Thickness 180-300 ft. (I-2108)

Je - Entrada Sandstone (Middle Jurassic)

Light tan to white, locally red banded, very fine grained sandstone and silty sandstone. Generally flat bedded and weakly to moderately cemented. Lower part locally white to red, fine to medium grained, crossbedded. Thickness 300-500 ft. (I-2108)

Jcu - Carmel Formation, upper member (Middle Jurassic)

(Peterson and Pipiringos, 1979) Red, pale orange, and white, fine grained sandstone, silty sandstone, and mudstone. Upper part contains tan, thin bedded, fine grained silty sandstone, mudstone, and very thin, tan to white gypsum beds. Lower part contains a light gray, thin bedded limestone marker bed (Jcul) about 15 ft thick and located 150 ft above base. Unit is about 600-700 ft thick. (I-2108)

Jcul - Carmel Formation, limestone marker bed (Middle Jurassic)

Thin bedded limestone marker bed about 15 ft thick and located 150 ft above base. (I-2108)

Jcgt - Carmel Formation, gypsiferous member and Page Sandstone (Middle Jurassic)

Gypsiferous member is thick bedded, white, massive gypsum in lower part and thin bedded, interbedded gray or greenish gray mudstone, gypsiferous mudstone, and gypsum in upper part; about 30-50 ft thick. Thousand Pockets Tongue of Page Sandstone is white, yellowish gray, or rust colored, fine grained, crossbedded sandstone; usually forms cliffs with overlying gypsum; pinches out northwestward; about 5 15 ft thick. (I-2108)

Jcb - Carmel Formation, banded member (Middle Jurassic)

Red, fine grained sandstone and mudstone, and thin bedded, interbedded gray to white sandstone and greenish gray mudstone. Thins eastward and grades into Thousand Pockets Tongue of Page Sandstone (Peterson and Pipiringos, 1979, p. 13 14). About 100 ft thick. (I-2108)

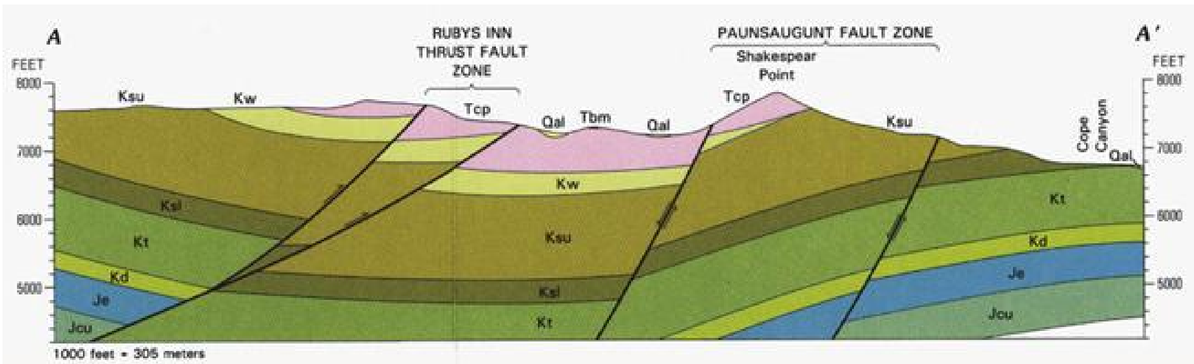
Jcl - Carmel Formation, limestone member (Middle Jurassic)

Gray, thin bedded, cliff forming limestone, and thin bedded, interbedded gray mudstone, shale, and gypsum, mostly in lower part. Only upper part exposed in map area. Unconformable on underlying Lower Jurassic Navajo Sandstone. About 120 ft thick. (I-2108)

Geologic Cross Sections

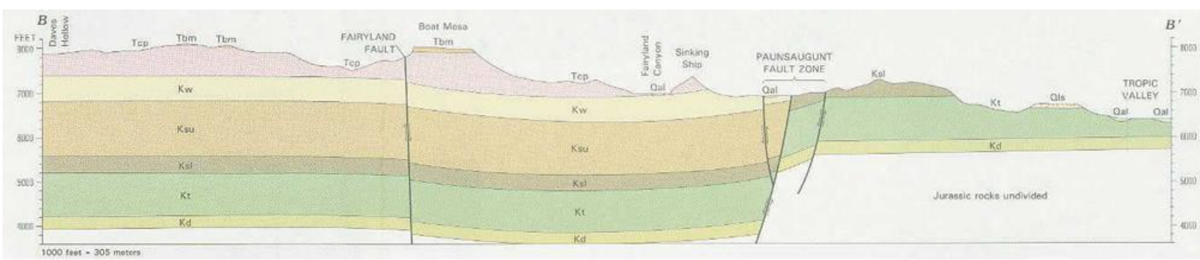
The geologic cross sections present on source map used for Bryce Canyon National Park, Utah (BRCA) are presented below.

Cross Section A-A'



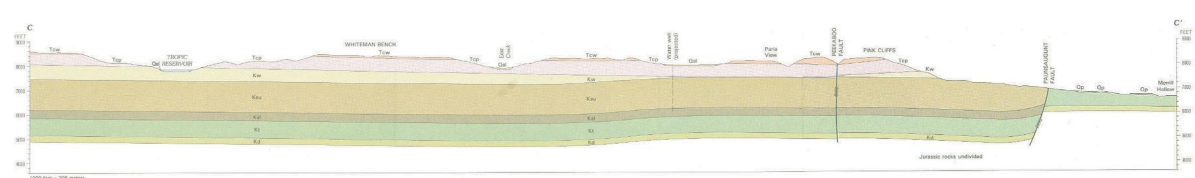
Extracted from [(I-2108)](). Cross Section A-A' on source map.

Cross Section B-B'



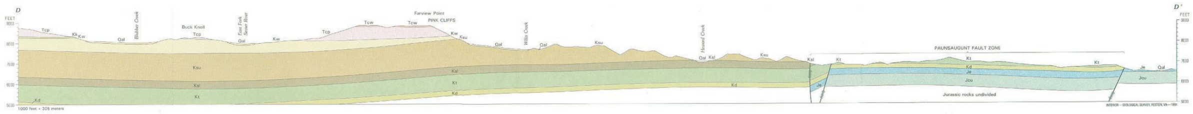
Extracted from [(I-2108)](). Cross Section B-B' on source map.

Cross Section C-C'



Extracted from [(I-2108)](). Cross Section C-C' on source map.

Cross Section D-D'



Extracted from (I-2108). Cross Section D-D' on source map.

GRI Source Map Citations

The GRI digital geologic-GIS map for Bryce Canyon National Park, Utah (BRCA) was compiled from the following source map:

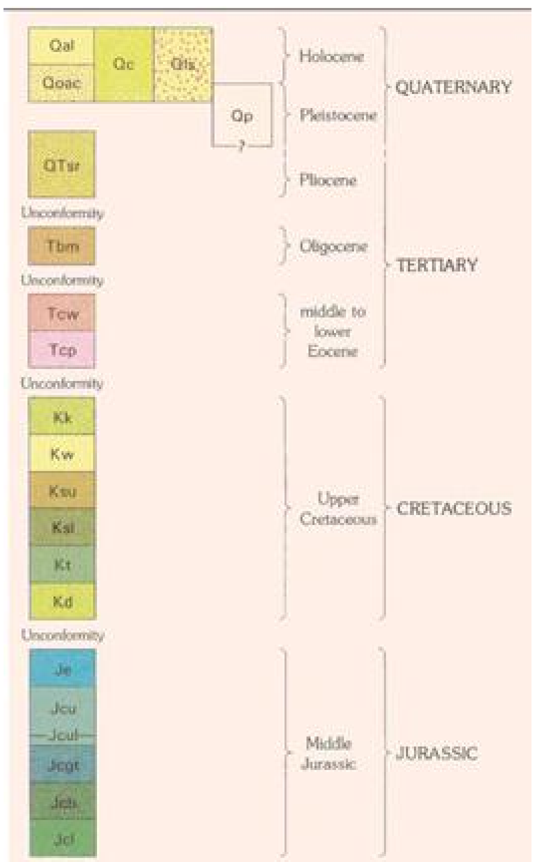
Bowers, W.E.., 1990, Geologic Map of Bryce Canyon National Park and Vicinity, Southwestern Utah: U. S. Geological Survey, Miscellaneous Investigations Series Map, I-2108 scale 1:24,000. (GRI Source Map 252)

Additional information pertaining to the source map is also presented in the Source Map Information (MAP) table included with the GRI geology-GIS data.

Bowers, 1990 (USGS I-2108)

Bowers, W.E.., 1990, Geologic Map of Bryce Canyon National Park and Vicinity, Southwestern Utah: U. S. Geological Survey, Miscellaneous Investigations Series Map, I-2108 scale 1:24,000

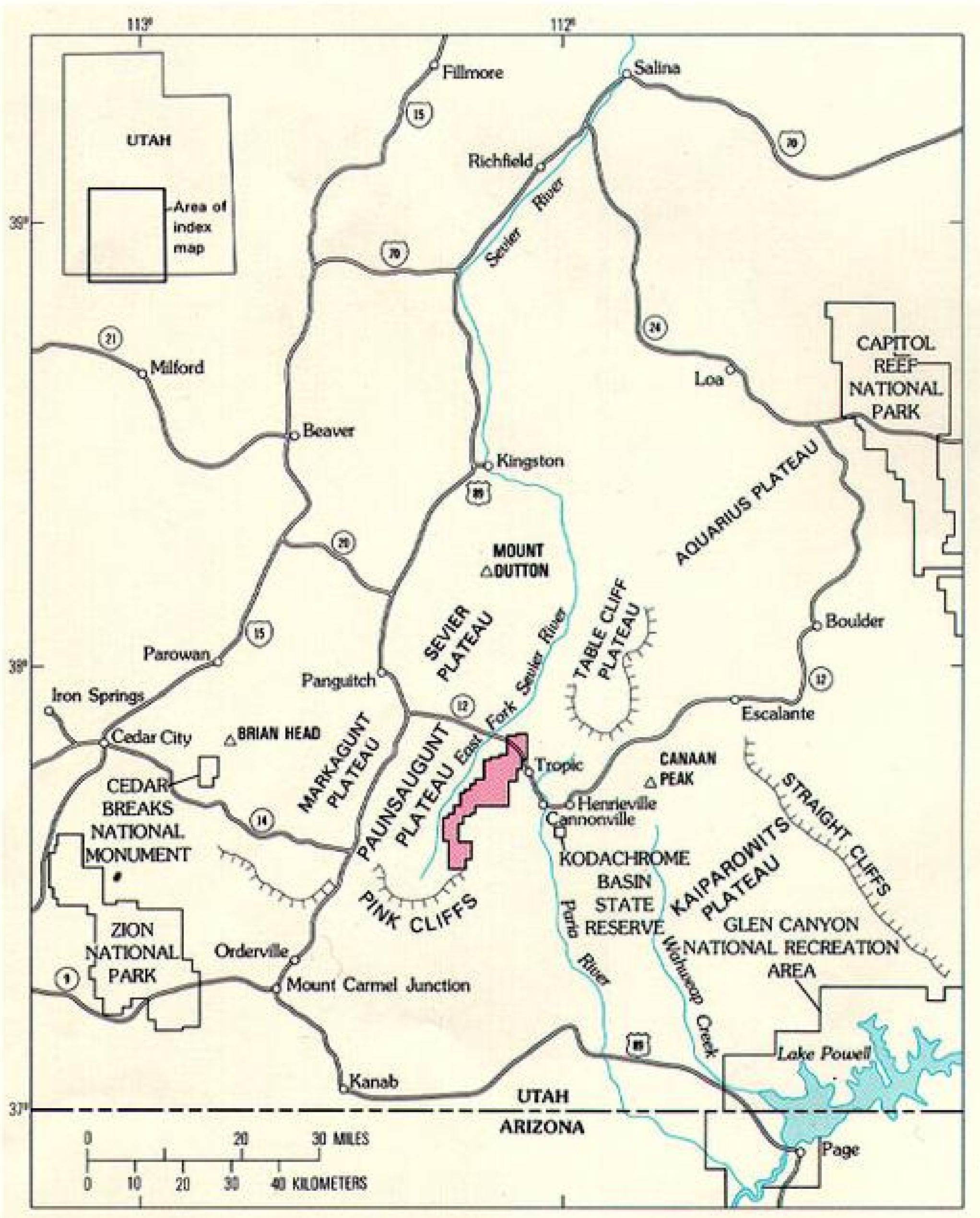
Correlation of Units Figure



Extracted from (I-2108).

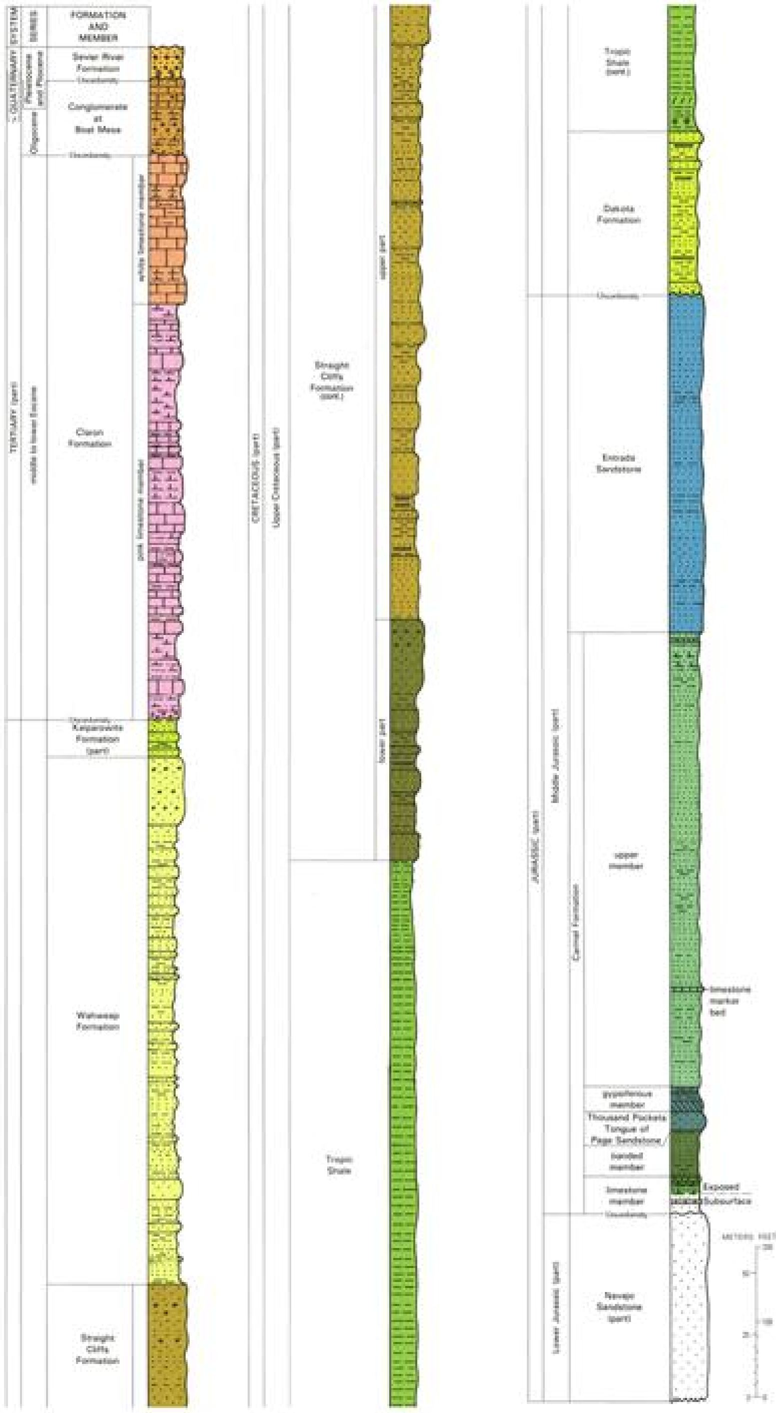
Location Map

Index map of central southern Utah showing regional setting of Bryce Canyon National Park (colored).



Extracted from (I-2108).

Stratigraphic Section Figure



Extracted from (I-2108). The stratigraphic column is presented in three adjacent columns with the left/first column being the top of the section, the middle column the middle of the section, and the right/last column the bottom of the section.

Bowers, 1990 Report

GEOLOGIC MAP OF BRYCE CANYON NATIONAL PARK AND VICINITY, SOUTHWESTERN UTAH
by
William E. Bowers, 1990
I-2108

INTRODUCTION

Bryce Canyon National Park is located along the eastern escarpment of the Paunsaugunt Plateau, which, along with the Markagunt Plateau to the west, forms the southernmost of the High Plateaus of Utah. The park's unique scenery has been created by forces of differential erosion acting on colorful rocks exposed along and below the rim of the plateau. Park headquarters and major scenic viewpoints that lie on or near the rim of the plateau are accessible from Utah Highway 12, which connects with U.S. 89 about 12 mi west of the park. More remote parts of the park are located in canyons beneath the rim and are accessible only by foot, along horse trails, or from a few unimproved dirt roads that approach the park boundary from the east or south.

The Paunsaugunt Plateau forms the western side of the Paria amphitheater, a broad drainage basin of the headwaters of the south-flowing Paria River. The Paria amphitheater is bounded on the northeast and east by the Table Cliff Plateau and the Kaiparowits Plateau, respectively. Erosion by tributaries of the Paria River east of the park has cut canyons into the face of the plateau at varying rates and intensities, creating spectacular vistas from viewpoints along the rim and from trails that lead down from the rim to wind among the colorful rocks within the canyons.

Westward from the east rim of the Paunsaugunt Plateau, low-gradient tributaries of the north-flowing East Fork of the Sevier River drain the plateau surface, creating a more subdued topography. Pine, spruce, and fir forests cover much of the higher parts of the plateau, which rises to more than 9,000 ft at the south end. Juniper, pinyon pine, and sagebrush are common at lower altitudes on the plateau surface.

Below the east rim of the plateau, largely unvegetated cliffs and steep slopes give way to gentler slopes, ridges, and canyon bottoms containing stands of Ponderosa pine or clumps of oak brush. Variations in temperature and precipitation are due largely to differences in elevation, which ranges from about 6,300 ft near the town of Tropic to 9,300 ft near Crawford Pass southwest of the park. Bezy (1980, p. 30) described three biological "life zones" within the park in order of increasing altitude: the Upper Sonoran, Transition, and Canadian zones. Each zone is characterized by its own type of plant and animal life, but zone boundaries are not sharp and overlap or merge depending upon local conditions.

Numerous publications and exhibits describing the geology, flora, and fauna of the park are available at the visitor center at park headquarters. The most comprehensive early report on the geology and geography of the Paunsaugunt region is a classic paper by H.E.

Gregory (1951). Brox (1961) studied the geology and erosional development of the northern part of Bryce Canyon National Park and described in detail the lithology of some stratigraphic units. An appraisal of the groundwater resources of the Bryce Canyon area was done by Marine (1963). Lindquist (1977, 1980) divided the park into three segments on the basis of distinctive erosional features, and discussed in detail the nature of scarp development in each segment. Lundin (1987) made a detailed study and analysis of thrustrelated structures in the northern part of the park and in the adjacent Johns Valley area to the north. A discussion of the park's badlands topography by John Bezy, former naturalist at Bryce Canyon National Park, is included in this report.

This report is a product of a collaborative effort of the U.S. Geological Survey and the U.S. National Park Service to update geologic knowledge of the park and to produce a new large-scale map of the area. Recent geologic mapping in the Kaiparowits Plateau and Table Cliff Plateau region by the U.S. Geological Survey and others shows a need for some revision of stratigraphy within the Bryce Canyon area. This report attempts to reconcile some differences in stratigraphic boundaries as mapped by Gregory (1951) by applying new data obtained by extensive geologic mapping in areas east of the Bryce Canyon region.

STRATIGRAPHY

Stratigraphic units are described from youngest to oldest because much of the striking scenery within Bryce Canyon National Park has been created by erosion of the colorful Tertiary rocks in the upper part of the section. Underlying Cretaceous rocks, although present over large areas, are less conspicuous because of their drab colors and poorer exposure due to cover by soil and vegetation. Jurassic rocks, although colorful and interesting, are exposed only in the southeastern part of the map area.

QUATERNARY DEPOSITS

Several types of surficial deposits are present in the map area. Alluvial and valley-fill deposits occur along most major stream valleys. Alluvium may be absent in narrow tributary canyons and in major drainage channels where more rapid down-cutting is evident, such as Bull Valley in the southeast. Youngest valley alluvium is commonly entrenched by steep gullies of the present erosion cycle. Gullying in Holocene sediments is due in some measure to human activities such as grazing and forestry operations. Colluvium, slopewash, and mass-wasting debris cover bedrock in many places. Soil and vegetation cover some areas mapped as bedrock, particularly on top of the plateau. Areas mapped as colluvium may include talus and landslide debris. Several small areas are underlain by landslide deposits, the largest of which is just northwest of the town of Tropic.

Gravel-capped surfaces that bevel bedrock and slope gently away from upland areas are common in the eastern part of the map area. These pediment deposits lie from 100 to 400 ft above present drainage channels and consist of poorly to moderately indurated sediments composed of silt, sand, and pebble to bouldersize gravel derived primarily from Tertiary limestone and conglomerate, and secondarily from Cretaceous sandstone and shale. The most extensive of these older erosion surfaces was named the Cannonville erosion surface by Gregory and Moore (1931, p. 133) and Gregory (1951, p. 101) and considered to be of Pleistocene to Pliocene age.

Robison (1966, p. 30) compared the pediment deposits in the Tropic area with deposits near Capital Reef National Park and suggested a pre-Wisconsin (prelate Pleistocene) age. Hornbacher (1985) described channel and sheet conglomerate near Kodachrome Basin State Reserve south of Cannonville and also favored a Pleistocene to Pliocene age. The pediments are in various stages of dissection during the present erosion cycle.

The Sevier River Formation, in part of Quaternary age, is discussed with the Tertiary rocks.

TERTIARY ROCKS

General discussion

One of the first explorers to describe the Tertiary rocks of the region was E.E. Howell (1875, p. 270-271), who examined more than 1,600 ft of pink and white limestone, marl, and conglomerate in the Table Cliff Plateau. C.E. Dutton (1880, p. 204), a member of the Powell Survey of 1875-77, examined and described similar beds in the Markagunt and Paunsaugunt Plateaus and named them the "Pink Cliff series." G.B. Richardson (1909, p. 382) introduced the name Wasatch Formation to southern Utah from the type area in southwestern Wyoming and northeastern Utah (Hayden, 1869, p. 91). Largely because of a similar appearance and occurrence in a similar part of the stratigraphic column, Richardson assigned the pink and white Tertiary limestone in the Paunsaugunt Plateau to the Wasatch Formation. Gregory and Moore (1931, p. 114-116) also used the name Wasatch and described an erosion surface separating the Tertiary rocks from Cretaceous rocks in the region.

Gregory (1951), in his report on the Paunsaugunt Plateau, recognized two formations in the youngest rocks of the area resting unconformably on Cretaceous rocks, the Quaternary and Tertiary Sevier River Formation, and the Tertiary Wasatch Formation. In later reports that were actually published before his Paunsaugunt paper, Gregory (1944,1945,1949) assigned his "white Wasatch" at Bryce Canyon to the Brian Head Formation, which he had named in Cedar Breaks National Monument. However, recent workers in southern Utah have abandoned the term Brian Head because the type section near Cedar Breaks was later found to include the feather edge of most Tertiary units in the southern High Plateaus (Threet, 1952, 1963; Anderson and Rowley, 1975).

Many recent workers object to the use of the name Wasatch in southern Utah because of differences in age and lithology between these rocks and those of the type area of the Wasatch Formation more than 200 mi to the northeast. Spieker (1946, p. 132-139) did not use the name Wasatch in central Utah and divided the Tertiary units in descending order into the Green River Formation, Flagstaff Limestone, and North Horn Formation.

Leith and Harder (1908, p. 41-44), recognizing a need for a local name, proposed the name "Claron limestone" for lower Tertiary strata in the Iron Springs district west of Cedar City. The name Claron was first extended into the High Plateaus by Mackin (1954; 1960, p. 101) and by Cook (1957, p. 37; 1960, p. 32; 1965, p. 54) and Averitt (1967). Averitt suggested correlation of the Claron with the Wasatch Formation mapped by Cashion (1967b) along the south rim of the Markagunt Plateau. Other names proposed for the pink and white limestone of southern Utah were "Cedar Breaks Formation" by Schneider (1967, p.153) and "Bryce Canyon beds" by McFall (1955). Robison (1966) preferred the name Claron to Wasatch in the Table Cliff and Paunsaugunt Plateaus regions, and Rowley (1968) and Rowley and others (1987) used the name Claron Formation for similar beds in the southern Sevier Plateau, which adjoins the Paunsaugunt Plateau on the north.

Bowers (1972), however, working in the Table Cliff Plateau too far east for direct correlation with the Claron, observed lithologies, particularly in the upper part of the section, that did not agree with published descriptions of Gregory's "white Wasatch" or the white Claron rocks. Bowers retained the name Wasatch and divided it into three informal members: in descending order, the variegated sandstone, white limestone, and pink limestone members. The variegated sandstone member in the Table Cliff Plateau consists of interbedded red, white, or gray sandstone, siltstone, and mudstone and a basal dark chert-pebble conglomerate.The white and the pink beds of the Paunsaugunt region appear to be correlative with the white and the pink members in the Table Cliff Plateau, and with the white and pink limestone in the lower part of the Claron Formation mapped by Rowley and others (1987) near the East Fork of Hunts Creek in the southeastern Sevier Plateau. The variegated member is not present in the Paunsaugunt Plateau unless it is equivalent, in part, to light-colored conglomeratic beds resting unconformably on the white limestone in the Bryce Canyon area. Rocks similar in lithology and color to the variegated sandstone member occur within the upper Claron rocks of the southern Sevier Plateau, but no detailed correlations have been made. Similarities in gross lithology and stratigraphic sequence between the Wasatch Formation in the Table Cliff Plateau and the Green River, Colton, and Flagstaff rocks in central Utah were noted by Bowers (1972, p. 31-32).

Although the name Wasatch Formation has traditionally been used for the Bryce Canyon strata, most geologists presently involved in the region prefer the name Claron Formation for the white and pink limestone in the Paunsaugunt Plateau. To be consistent with stratigraphic terminology used to the north and west of the map area, the name Claron Formation is used in this report.

Extensive volcanism in middle Tertiary time deposited lava flows, volcanic mudflow breccia, and ash-flow tuff on the Claron rocks in the southern Sevier Plateau north of the Bryce Canyon area; no volcanic rocks exist in the map area, where if ever present, they were removed by erosion. A summary of the volcanic stratigraphy of the southern High Plateaus and southeastern Great Basin is included in Anderson and Rowley (1975) and Rowley and others (1979).

Sevier River Formation

The Sevier River Formation was named by Callaghan (1938, p. 100-101) for sediments deposited in structural valleys and down-faulted areas of southwestern Utah during Cenozoic block faulting. Gregory (1951, p. 5254) assigned fluvial volcanic conglomerate, siltstone, and clay along the South Fork of the Sevier River just west of the Paunsaugunt Plateau to the Sevier River Formation, and Crawford (1951) described a diatomaceous earth deposit of Pliocene age in rocks on the west side of the Paunsaugunt Plateau that Gregory had correlated with the Sevier River Formation. Anderson and Rowley (1975) discussed the distribution and lithology of the Sevier River Formation in the southwestern High Plateaus and included a summary of the literature pertaining to the formation. The present outcrops of Sevier River Formation are considered to be remnants of more extensive valley-fill deposits. The age of the deposits apparently differs between areas, and ranges from Pleistocene to Miocene.

Rocks assigned to the Sevier River Formation (QTsr) within the map area occur only in the northeast corner, near the heads of Little Henderson Canyon and Cedar Canyon. The unit is predominantly light brown or brownish-gray, flat-bedded, conglomeratic sandstone and interbedded conglomerate. Clasts consist of brown and gray, subrounded to subangular volcanic pebbles and cobbles, and subordinate subangular limestone pebbles in a sandy calcareous matrix. The conglomerate beds contain scattered cobbles as much as 8 in. in diameter. Volcanic clasts were probably derived from the Miocene Mount Dutton Formation (Anderson and Rowley, 1975) northwest of the map area. The formation is probably of Pleistocene and Pliocene age in the map area.

Conglomerate at Boat Mesa

H.E. Gregory (1951, p. 50), in his report on the Paunsaugunt region, referred to the white beds that cap Whiteman Bench and the light-colored beds that cap Bryce Point and Boat Mountain (now Boat Mesa) as "white Wasatch." Based on a later interpretation that was actually published before the Paunsaugunt paper, Gregory (1949, p. 983) correlated these beds with his Brian Head Formation near Cedar Breaks National Monument. Because of the problems associated with use of the name Brian Head, I propose the informal name conglomerate at Boat Mesa for the conglomeratic beds on Boat Mesa and Bryce Point. Brox (1961) referred to the same beds as unnamed Tertiary conglomerate. The white limestone that caps Whiteman Bench and the conglomerate at Boat Mesa are different stratigraphic units separated by an unconformity. From Sunset Point northward the white limestone member of the Claron is cut out and the conglomerate at Boat Mesa lies on the pink limestone member.

The conglomerate at Boat Mesa (Tbm) consists of light brown to light gray calcareous sandstone and conglomeratic sandstone with tan, gray, or black chert and tan quartzite pebbles, and white limestone and conglomeratic limestone with chert and quartzite pebbles. The thickest section is at Boat Mesa where the unit is about 100 ft thick. At Bryce Point, where the unit lies on the white limestone member, it is about 40 ft thick. The conglomeratic beds locally contain small angular limestone fragments of underlying Claron Formation.

In the absence of fossil evidence or other age criteria, the age of the conglomerate at Boat Mesa is uncertain. The beds rest unconformably on both the white and pink limestone members of the Claron and appear to postdate older structural deformation that involved white Claron. Volcanic clasts seem to be absent from the conglomerate, although Gregory (1951, p. 50) referred to volcanic clasts in his "white Wasatch," which he later called Brian Head Formation. Because Gregory did not mention specific localities, it seems likely he was referring to volcanic clasts in white beds much higher in the Claron Formation than are present in the Paunsaugunt Plateau. An age of Oligocene is inferred for the conglomerate at Boat Mesa.

Claron Formation

The white, pink, and red limestones that overlie drab-colored Cretaceous rocks and form the rim of the Paunsaugunt Plateau and the spectacular hoodoos, fluted cliffs, columns, and spires of Bryce Canyon are part of the Claron Formation. This unit is divided into two informal members, an upper white limestone member as much as 300 ft thick, and a lower pink limestone member 400-700 ft thick.

The white limestone member (Tew) is present only on higher parts of the Paunsaugunt Plateau. The unit is represented in the massive white cliff formed by the caprock at Yovimpa Point at the south end of the park, and it forms Whiteman Bench and other relatively flat-topped parts of the plateau, extending from Natural Bridge to near Sunset Point. The member is not present north of Sunset Point, where it was removed by erosion prior to deposition of the conglomerate at Boat Mesa.

The white limestone member is generally a white, grayish-white, and cream, massive, cliff-forming limestone, somewhat more homogeneous in texture and composition than the underlying pink limestone member. Brox (1961, p. 30) reported the white limestone to be composed of 70-90 percent carbonates, 5-30 percent silt, and less than 10 percent sand. Near Bryce Point and Inspiration Point the member becomes thinner bedded and less distinct and forms the caprock in the Wall of Windows. The member attains a maximum thickness of about 250 ft at Yovimpa Point and about 300 ft at Bryce Point and Inspiration Point. The member was probably deposited in a lacustrine or lowenergy fluvial environment. At one locality on Whiteman Bench west of the park, the unit contains unidentified freshwater gastropods.

Much of the striking scenery in Bryce Canyon National Park was created by differential erosion of colorful sedimentary rocks of the pink limestone member (Tep), such as Silent City, Queens Garden, Fairyland, and other spectacular badlands topography in Bryce Canyon. Similar scenery can be seen in correlative pink or red limestone at Red Canyon and Cedar Breaks National Monument.

The pink limestone member consists mostly of interbedded very fine grained limestone, calcareous mudstone, and fine-grained clastic sedimentary rocks containing varying proportions of carbonate clasts and carbonate cement. Impure limestone with varying amounts of clay and silt and lesser amounts of sand are common. Brox (1961) found that the less resistant beds in his measured sections contained higher proportions of silt and clay. Lindquist (1980, p. 37) reported significant amounts of dolomite in the more resistant limestone beds. Color of the member ranges from pale pink to red, pale orange, tan, and white; color of individual beds varies under changing light conditions. Dutton (1880, p. 204) described these rocks as having a "flesh of watermelon" color. The beds are variable in texture and composition, both laterally and vertically, and bedding features are often indistinct.

A gray to red basal conglomerate, generally less than 20 ft thick, consisting of well-rounded varicolored pebbles and cobbles of quartzite, chert, and lesser amounts of limestone is present locally. The base is commonly of calcareous sandstone or sandy mudstone, grading upward to sandy or silty limestone.

The pink limestone member was probably deposited largely in low-energy fluvial and lacustrine environments. Coarser clastic channel deposits form less than 1 percent of these beds in the map area. Workers from Kent State University under the direction of JJ. Anderson are involved in a study of Claron deposition in the Bryce Canyon-Cedar Breaks area. Their findings indicate that indistinct bedding features, common throughout much of the Claron Formation, have resulted from obliteration of primary sedimentary structures by pedogenic processes (Mullet and others, 1988).

No evidence for precise dating of the Claron Formation has been found in the Paunsaugunt region. Gregory (1951) assigned the formation to the Eocene. Freshwater gastropods collected from the white limestone member in the Table Cliff Plateau were dated as middle to early Eocene (D.W. Taylor, in Bowers, 1972, p. 26), and the underlying pink limestone was tentatively assigned an age of Eocene to Paleocene.

In the southern Sevier and northern Markagunt Plateaus, beds assigned to the uppermost Claron contain tuffaceous material that has been dated (KAr) as Oligocene. Samples collected from the uppermost Claron in the northern Markagunt Plateau by E.G. Sable (oral commun., 1988) were dated at 29.1-32.4 million years. Volcanism in southern Utah probably began in early Oligocene time (Rowley and others, 1979, p. 5); however, the beds assigned to the upper part of the Claron in the southern Sevier Plateau are not present near Bryce Canyon. In the absence of definite age indicators from the Claron rocks near Bryce Canyon, an age of middle to early Eocene is assigned. Elsewhere the Claron includes rocks as young as Oligocene.

CRETACEOUS ROCKS

General discussion

H.E. Gregory's professional paper on the geography and geology of the Paunsaugunt region (Gregory, 1951) was based on geographic and stratigraphic records compiled from 1922 to 1936, and on geologic mapping from 1938 to 1940. Gregory, conforming to his stratigraphic usage in adjacent areas, recognized five subdivisions of Cretaceous rocks in the Paunsaugunt Plateau. The recognized formations, in descending order, were the Kaiparowits Formation, Wahweap Sandstone, Straight Cliffs Sandstone, Tropic Shale, and Dakota Sandstone.

In the Paunsaugunt region, Gregory (1951, p. 34) had difficulty mapping a Wahweap-Straight Cliffs boundary and he said "No persistent features serve to separate the Straight Cliffs and Wahweap and these two formations are accordingly mapped as a unit." Gregory (1951, p. 39) indicated that "Tracing and retracing of 20 miles of supposed guide beds and measurement of scores of test sections brought the discouraging conclusion that each tentative subdivision included features of all the others."

Extensive later geologic mapping by the U.S. Geological Survey and others in the Kaiparowits and Table Cliff Plateaus east of the Paunsaugunt region (Robison, 1966; Bowers, 1973, 1975) resulted in recognition of a well defined break between the Wahweap and Straight Cliffs Formations. The contact can be traced from the Table Cliff Plateau, around the headwaters of the Paria River drainage, to the northeast edge of the Paunsaugunt Plateau. There the continuity of the beds is disrupted by faulting along the Paunsaugunt fault zone.

West of the Paunsaugunt fault zone, in the northeastern part of the map area, the Wahweap-Straight Cliffs contact can be recognized in Johns Valley. Near Bristlecone Point the contact reappears and can be traced southward to the south end of the Paunsaugunt Plateau, except where removed by erosion in the Sheep Creek drainage. Unpublished mapping in the Alton and Skutumpah Creek area of the southwestern Paunsaugunt Plateau (Terry Tilton, Utah State University student, oral commun., 1976) and reconnaissance mapping by the author show that the contact can be traced westward across the south end of the Paunsaugunt Plateau and then northward to the Kanab Creek drainage on the west side of the plateau.

The gray to brown sandstone and mudstone of the Wahweap Formation and the underlying uppermost light colored conglomeratic sandstone beds of the Straight Cliffs Formation of this report were assigned by Gregory (1951) to the Kaiparowits Formation.

Kaiparowits Formation

The Kaiparowits Formation was named by Gregory and Moore (1931, p. 106) for Kaiparowits Peak (now Canaan Peak) about 15 mi east of Tropic, Utah. In the western Kaiparowits Plateau, the formation is a thick (more than 2,500 ft) sequence of predominantly very fine grained, greenish-gray to bluish-gray sandstone with a "salt and pepper" appearance. The formation contains subordinate gray sandy mudstone and buff to brown, fine-grained lenticular sandstone interbeds that may contain vertebrate fossils. Much of the formation is composed of poorly cemented sandstone that weathers to badlands topography. The best exposures of the Kaiparowits Formation are in the area locally known as "The Blues" a few miles east of the town of Henrieville on Utah Highway 12.

In the Paunsaugunt Plateau, nearly all of the Kaiparowits Formation and locally much of the underlying Wahweap Formation was removed by erosion prior to deposition of the Claron Formation. Strata shown on Gregory's (1951) map as Kaiparowits Formation along the eastern edge of the plateau beneath the Tertiary limestone are actually the Wahweap Formation and the uppermost conglomeratic sandstones of the Straight Cliffs Formation. The only rocks in the map area that are assigned to the Kaiparowits Formation (Kk) are a few light brown, very fine grained sandstone and gray sandy mudstone beds that occur above light-colored conglomeratic sandstone of the Wahweap Formation west of Sand Pass, along Blubber and Upper Kanab Creeks. Exposures are poor and beds are usually covered by limestone debris from the overlying Claron Formation. The Kaiparowits Formation was deposited in fluvial, floodplain, and lacustrine environments.

Gregory and Moore (1931, p. 107) assigned an age of Late Cretaceous (Maastrichtian-Campanian) to the Kaiparowits Formation based on freshwater molluscs identified by J.B. Reeside, Jr. Lohrengel (1968) considered the formation to be latest Cretaceous on the basis of a palynological study. Palynomorphs identified by R.H. Tschudy (Bowers, 1972, p. 19) indicated a Campanian age for the lower part of the Canaan Peak Formation, which unconformably overlies the Kaiparowits Formation in the northern Kaiparowits and Table Cliff Plateaus.

Wahweap Formation

The Wahweap Sandstone was named by Gregory and Moore (1931, p. 104-106) for outcrops along Wahweap Creek in the Kaiparowits Plateau, where the formation is composed of gray to tan mudstone and interbedded buff to brown fine-grained fluvial sandstone ranging from 1,100 to 1,500 ft thick. Peterson and Waldrop (1965, p. 6566) applied the more appropriate name Wahweap Formation because mudstone predominates in the lower part of the formation and sandstone in the upper part. In the Kaiparowits region the Wahweap Formation is capped by a cliff-forming, fine to coarsegrained, light gray to white, locally conglomeratic sandstone, 200-350 ft thick. Lithologically, the unit closely resembles the uppermost conglomeratic sandstone beds of the Straight Cliffs Formation.

The Wahweap Formation (Kw) is represented in the eastern rim of the Paunsaugunt Plateau by 200-400 ft of westerly dipping buff to light brown sandstone and gray to tan mudstone. The unit lies between the white conglomeratic sandstone at the top of the Straight Cliffs Formation and the pink and white limestone members of the Claron Formation that cap the plateau. The Wahweap Formation thickens westward beneath the Tertiary rocks to about 700 ft where the formation is exposed along the East Fork of the Sevier River in the center of the plateau.

The uppermost beds of the Wahweap are composed of light gray or white, fine to coarse-grained, friable conglomeratic sandstone. The best exposures of the upper Wahweap are in the area of Sand Pass, which is west of Buck Knoll and near Blubber Creek. The formation is poorly exposed in the central part of the plateau because of the development of mature topography where slopewash, soil, and forest cover obscure much of the bedrock. The Wahweap Formation appears to be of fluvial, floodplain, and possibly lacustrine origin.

No fossils suitable for age determination were found in the Wahweap Formation in the Paunsaugunt region. In the Kaiparowits Plateau a few nonmarine invertebrate and vertebrate fossils and plants of Late Cretaceous age were collected by Peterson (1969a, p. 94).

Straight Cliffs Formation

The Straight Cliffs Sandstone was named by Gregory and Moore (1931, p. 91) for exposures along the Straight Cliffs escarpment, which forms the eastern edge of the Kaiparowits Plateau south of Escalante, Utah. Peterson and Waldrop (1965) recognized that the Straight Cliffs contains significant amounts of rocks other than sandstone and applied the more appropriate name Straight Cliffs Formation. Peterson (1969b) later divided the Straight Cliffs Formation (lower Campanian to middle Turonian) in the Kaiparowits Plateau into four members, from youngest to oldest: the Drip Tank, John Henry, Smoky Hollow, and Tibbet Canyon Members. He also recognized an unconformity between the John Henry and the Smoky Hollow Members in the eastern Kaiparowits region.

The Drip Tank Member (lower Campanian) is a light gray to white, generally massive, fine to coarse-grained, crossbedded, fluvial sandstone containing lenses of pebble conglomerate in the upper part. In the Kaiparowits region the unit is commonly a resistant cliff former that ranges from 200-500 ft thick. Equivalent beds at the top of the formation in the Paunsaugunt Plateau are generally 150-200 ft thick and form cliffs, steep slopes, and sandy or pebble-covered benches. The white to light gray sandstone beds below the rim south of Natural Bridge viewpoint, and well exposed in steep slopes and cliffs at the head of Mud Canyon, are equivalent to the Drip Tank Member.

The John Henry Member (lower Campanian to middle Coniacian) consists of light brown, buff, or gray, fine- to medium-grained sandstone, buff or gray mudstone, dark carbonaceous mudstone, and coal. In the Kaiparowits Plateau the member contains extensive thick coal beds and ranges from about 600-1,100 ft thick. The member includes a marine and a nonmarine facies, with marine beds predominant in the northeast (Peterson, 1969b, p. 17; Zeller, 1973a, b). In the Paunsaugunt region beds equivalent to the John Henry Member of the Straight Cliffs contain little coal and probably average about 800 ft thick.

In this report beds equivalent to the Drip Tank and John Henry Members are mapped as a unit referred to as the upper part of the Straight Cliffs Formation (Ksu), averaging about 1,000 ft thick in the Paunsaugunt Plateau. A test well drilled for water by the National Park Service near the head of East Creek and west of Paria View (Marine, 1963, pl. 26) indicates about 1,250 ft of the upper part of the Straight Cliffs. Marine or brackish water sedimentary rocks may occur in the lower 200-300 ft of the upper part of the Straight Cliffs, but most of the unit represents fluvial or floodplain deposits.

The Smoky Hollow Member (upper to middle Turonian) is composed of interbedded light brown to gray, fine-grained sandstone, mudstone, carbonaceous mudstone, and coal, and was deposited in fluvial, floodplain, and swamp environments (Peterson, 1969b, p. 9). The top of the Smoky Hollow Member is marked throughout much of the Paunsaugunt region by a light gray to white conglomeratic sandstone (Calico bed of Peterson, 1969b), and in the eastern Kaiparowits by an intraformational unconformity not recognized in the Paunsaugunt region.

The Tibbet Canyon Member (middle Turonian) is predominantly a light brown, very fine grained, cliff-forming marine sandstone ranging from about 70 to 185 ft thick in the Kaiparowits Plateau. Equivalent beds at the base of the Straight Cliffs Formation in the Paunsaugunt Plateau are generally thinner, on the order of 30-50 ft thick. The Tibbet Canyon Member represents beach and shallow marine deposits.

In this report the Smoky Hollow and Tibbet Canyon Members of the Straight Cliffs Formation have been mapped as a unit referred to as the lower part of the Straight Cliffs Formation (Ksl), ranging from about 320 to 400 ft thick.

Tropic Shale

The Tropic Shale was named by Gregory and Moore (1931, p. 98100) for exposures near the town of Tropic just east of Bryce Canyon National Park. Gregory's Tropic included about 200 ft of interbedded sandstone, mudstone, and coal now assigned to the Dakota Formation. Gregory (1951, p. 34), in discussing the upper contact of the Tropic Shale, indicated that "in the absence of plain horizon markers the base of the Straight Cliffs is somewhat arbitrarily drawn." Lawrence (1965, p. 77) redefined the upper contact of the Tropic Shale at the base of the lowest prominent ledge-forming sandstone of the Straight Cliffs Formation, at the top of a transition zone of alternating mudstone and sandstone.

In the eastern Paunsaugunt Plateau and the Kaiparowits Plateau, the Tropic Shale (middle Turonian to upper Cenomanian) (Kt) is composed largely of non-resistant gray claystone, containing minor amounts of gray to buff, very fine grained sandstone and mudstone near the top and bottom. The upper part of the Tropic contains the middle Turonian ammonite zone of Colli*gnoniceras* woollgari (Peterson and Waldrop, 1965). Several limestone concretion zones that may contain marine fossils occur in the lower 100 ft. The lowermost part of the Tropic Shale contains the fossil zone of *Sciponoceras gracile* (Shumard), an uncoiled ammonite index fossil of late Cenomanian (early Late Cretaceous) age (Lawrence 1965, p. 87; Peterson and Waldrop, 1965, p. 60-62, fig. 3). Very thin bentonite beds are also present in the lower part of the Tropic. The Tropic Shale was deposited largely in an offshore marine environment. Thickness of the formation ranges from about 700 to 1,000 ft.

The Straight Cliffs Tropic contact is fairly well exposed in the vicinity of Bryce Canyon National Park near the northeast boundary from Cope Canyon in the north to Campbell Creek west of Tropic. West of the Paunsaugunt fault zone the Tropic Shale is exposed only in a small area just east of the park boundary south of Willis Creek.

Dakota Formation

The Dakota Formation was named by Meek and Hayden (1862) for sandstone, shale, and lignite in northeastern Nebraska. Gregory (1951, p. 34-35) assigned only the lowermost 30 ft of Cretaceous rocks to the Dakota(?) Sandstone in the Paunsaugunt region and described the unit as irregularly bedded sandstone containing lenses of shale, conglomerate, and coal. Gregory placed the upper limit of the Dakota just below the first fossiliferous shale or sandy shale, which he assigned to the Tropic. Gregory's (1951) map of the Paunsaugunt region shows the Dakota(?) Sandstone and Tropic Shale as an undifferentiated unit.

Cashion (1961), in mapping the Glendale-Orderville area, divided the Tropic Formation into an upper shaly member and a lower coal-bearing member. Lawrence (1965) redefined the Tropic Dakota boundary in the Kaiparowits region, placing the contact at the top of either the highest coal or ledge-forming sandstone beneath the nonresistant claystone of the Tropic Shale. This provides a stratigraphic break that is generally easily recognized and mapped in the Paunsaugunt region.

The Dakota Formation (Upper Cretaceous) (Kd) is exposed within Bryce Canyon National Park only near the eastern boundary at Yellow Creek, but good exposures occur east of the park boundary along Sheep Creek and Willis Creek, east of the Paunsaugunt fault. The formation consists of alternating sandstone, mudstone, carbonaceous mudstone, and coal. A basal conglomerate is present in places. The Dakota was deposited in floodplain, fluvial, and swamp environments, with the upper part representative of near shore coastal swamp, brackish water, or shallow marine environments (Peterson and Waldrop, 1965, p. 60).

The base of the Dakota Formation marks the boundary between Cretaceous and Jurassic rocks in the region. The Dakota lies on a beveled erosion surface on Jurassic rocks. The contact is, in most places, easily seen as a color change from drab gray or light brown mudstone and sandstone of the Dakota to red or white color banded sandstone in the underlying Jurassic rocks.

JURASSIC ROCKS

General discussion

A regional unconformity separates Cretaceous and Jurassic rocks in the Bryce Canyon area. The oldest Cretaceous rocks, the Dakota Formation, lie on the unconformity that bevels at a low angle rocks of Middle Jurassic age. The Upper Cretaceous Dakota lies on successively older Jurassic strata westward. No Jurassic rocks are exposed within the boundaries of Bryce Canyon National Park, but the upper part of the Jurassic sequence is exposed in the eastern part of the map area from Yellow Creek southward.

Gregory (1951, p. 31) assigned about 650 ft of red and white sandstone exposed beneath his Dakota(?) Sandstone along the eastern flank of the Paunsaugunt Plateau to his Winsor Formation; the type area of the Winsor is in Winsor Cove (Gregory, 1950, p. 96-98) near the town of Mount Carmel southwest of the Paunsaugunt Plateau. Gypsiferous shale, sandstone, and limestone beneath his Winsor were incorrectly assigned by Gregory (1951, p. 29) to the Curtis Formation, which was named by Gilluly and Reeside (1928, p. 7879) in the San Rafael Swell northeast of the Paunsaugunt region.

More recent work (Wright and Dickey, 1963; Cashion, 1967a, b; Thompson and Stokes, 1970; Peterson and Pipiringos, 1979) has shown that Gregory's "Winsor" in the eastern Paunsaugunt region correlates with the Entrada Sandstone named by Gilluly and Reeside (1928, p. 76-78) in the San Rafael Swell in east-central Utah. Gregory's underlying misidentified "Curtis" was subsequently mapped as the gypsiferous member of the Carmel Formation (Cashion, 1967b) and later named the Paria River Member of the Carmel by Thompson and Stokes (1970).

The Entrada Sandstone is divided into three members in southwestern Utah: upper, middle, and lower (Peterson and Pipiringos, 1979, p. 30). Thompson and Stokes (1970) proposed the names Escalante, Cannonville, and Gunsight Butte Members for the upper, middle, and lower members, respectively. Subdivisions of the Entrada Sandstone were not mapped for this report.

Cashion (1967a) reduced the type Winsor Formation in rank to a member of the Carmel Formation and suggested that the name Winsor not be used east of the Paunsaugunt fault because the type Winsor in the Mount Carmel area is older than Gregory's "Winsor" of the northeast Paunsaugunt region. Thompson and Stokes (1970) subdivided the Carmel Formation into five members, and proposed new names for four of the members. Significant facies changes in the Carmel Formation east of the Paunsaugunt fault and other considerations led Peterson and Pipiringos (1979) to use informal units for subdividing the Carmel Formation. The units used by Cashion (1967a, b) and Peterson and Pipiringos (1979) are retained in this report.

Entrada Sandstone

The Entrada Sandstone (Middle Jurassic) (Je) in the Paunsaugunt region is predominantly white to lightgray, fine-grained, slope-forming sandstone or silty sandstone that is largely flat bedded and locally red color banded. Southeastward from the Paunsaugunt Plateau the lower part becomes massive, crossbedded, cliff-forming sandstone. The formation shows evidence of deposition in eolian and subaqueous environments. The Entrada thins southwestward due to erosion and is cut out by the pre-Dakota unconformity near Carly Knoll about 6 mi southwest of the south end of Bryce Canyon National Park.

Good exposures of the Entrada Sandstone occur near Yellow Creek south of Bulldog Bench, along Willis Creek between the northeastern and southwestern segments of the Paunsaugunt fault, and in the Bull Valley drainage around and south of Horse Mountain. Thompson and Stokes (1970, p. 45) reported about 365 ft of Entrada in Bull Valley. Near Yellow Creek the formation is estimated to be more than 500 ft thick. Most of the Entrada in the.Paunsaugunt region belongs to the middle and lower members due to the westward beveling of the formation by pre-Dakota erosion.

Carmel Formation

The upper member of the Carmel Formation (Middle Jurassic) (Jcu) is exposed in the southeastern part of the map area from the vicinity of Indian Hollow and Willis Creek southward. Thickest and best exposures occur in the Bull Valley drainage south of Horse Mountain. Peterson and Pipiringos (1979, p. 19) reported 672 ft of upper member in the Bull Valley area. The member is predominantly red to grayish-white, fine-grained sandstone or silty sandstone containing thin interbeds of gray mudstone and gypsiferous mudstone, and very thin beds of white gypsum near the top. A marker bed of gray, thin-bedded limestone (Jcul) about 15 ft thick occurs about 150 ft above the base of the upper member.

Lithologic similarity between the uppermost part of the upper member of the Carmel and the lower part of the Entrada in the Paunsaugunt area makes the contact between the two difficult to map. The contact is placed at the top of the highest gypsiferous mudstone or thin gypsum bed that occurs in the Carmel Formation.

The gypsiferous member of the Carmel Formation (Jcgt) is exposed only in the southeast corner of the map area in the Bull Valley drainage. The gypsiferous member consists of about 20-30 ft of interbedded gray or green mudstone, gypsiferous mudstone, and gypsum underlain by a thick bed of massive, cliff-forming white gypsum, locally as much as 25 ft thick.

The Thousand Pockets Tongue of the Page Sandstone (Middle Jurassic) (Jcgt) is present beneath the gypsiferous member in the southeast corner of the map area. The Thousand Pockets, previously considered to be a tongue of the Navajo Sandstone, is now known to be separated from the Navajo by a regional unconformity (Peterson and Pipiringos, 1979, p. 2930). The Thousand Pockets is white to yellowish-gray, finegrained, crossbedded sandstone that usually forms cliffs. In the map area the unit is about 5-15 ft thick and it pinches out northwestward. The Thousand Pockets was deposited in eolian and subaqueous environments. A few miles east of the map area the unit is as much as 100 ft thick.

The banded member of the Carmel Formation (Jcb) is exposed near the southeast corner of the map area and is predominantly red, fine-grained sandstone and mudstone with some interbeds of gray to white sandstone and greenish-gray mudstone. The banded member is about 100 ft thick in Bull Valley and thins eastward, grading into the Thousand Pockets Tongue of the Page Sandstone (Peterson and Pipiringos, 1979, p. 1314).

The limestone member of the Carmel Formation (Jcl), only the upper part of which is exposed in the southeast corner of the map area, is predominantly gray, thin-bedded, cliff-forming limestone with thin interbeds of gray mudstone, shale, or gypsum. The unit is about 120 ft thick in Bull Valley and thins eastward, where it is called the Judd Hollow Tongue of the Carmel Formation. The member thickens westward and elsewhere contains Middle Jurassic marine fossils. A regional unconformity (the J2 unconformity of Pipiringos and O'Sullivan, 1978) separates the Limestone member from the Navajo Sandstone.

Navajo Sandstone

The Navajo Sandstone is not exposed in the map area but the upper part is exposed in the bottom of Bull Valley a short distance east of the map boundary. The Navajo is a thick, cliff-forming, highly crossbedded sandstone that forms much of the spectacular scenery of southern Utah, particularly the deep canyons, massive cliffs, and rounded domes of Zion National Park and Glen Canyon National Recreation Area. The Navajo Sandstone is more than 2,000 ft thick in Zion National Park and probably more than 1,500 ft thick in the subsurface beneath Bryce Canyon National Park. The unit is predominantly eolian in origin.

Peterson and Pipiringos (1979) tentatively assigned the Navajo Sandstone an Early Jurassic age. However, the age was retained as Jurassic and Triassic(?) pending a more thorough published description of the paleontological evidence. Padian (1989) presented vertebrate faunal evidence for the Early Jurassic age of the Kayenta Formation in northern Arizona. Thus, the age of the Navajo Sandstone is considered to be Early Jurassic on the basis of its stratigraphic position above the Kayenta.

STRUCTURE

EXTENSIONAL (BASINRANGE TYPE) FAULTS

The north-striking Paunsaugunt fault zone marks the eastern limit of the Paunsaugunt Plateau and is the structure largely responsible for the existence of Bryce Canyon National Park. The western edge of the plateau was created by displacement along the Sevier fault, another major north-striking fault zone, which together with the Paunsaugunt fault forms the eastern and western boundaries of the Paunsaugunt crustal block. Displacement on both faults is normal, down to the west, and ranges from a few hundred feet to more than 1,400 ft. Lundin (1987) reported that seismic profiles indicate that basement offset on the Sevier fault may be as much as 2,900 ft.

The east-facing escarpment of the plateau was formed on the down-faulted side of the Paunsaugunt fault because of more rapid erosion of less resistant rocks exposed on the upthrown side of the fault. The escarpment retreated westward, leaving little topographic expression of the fault line. Most of the plateau is formed on essentially flat-lying strata that have a gentle regional dip to the northeast.

The Paunsaugunt fault is actually a complex fault zone consisting of one or two major faults and associated secondary faults of minor displacement. In places, particularly north of the map area, displacement is acccomplished by monoclinal flexure in addition to faulting (Robison, 1966; Lundin, 1987). Evidence of some left-lateral strike-slip movement on the Paunsaugunt fault has been reported by Davis and Krantz (1986).

In the map area the Paunsaugunt fault zone consists of two major segments that overlap in the vicinity of Yellow Creek. The northeastern segment has a separation of more than 1,200 ft where Utah Highway 12 crosses the fault and about 1,400 ft in Campbell Creek near Sinking Ship. The segment continues southward across Bryce Creek, Willis Creek, and the Bull Valley drainage and connects with a south-east striking splay of the southwestern segment south of Squaw Bench. The southwestern segment starts near Yellow Creek and separation increases rapidly southward to more than 1,200 ft at Willis Creek. Displacement is about 1,000 ft where the segment splays south of Squaw Bench. The segments are as much as 21/2 mi apart between Sheep Creek and Willis Creek. Dip of fault planes along the Paunsaugunt fault zone is generally G0°75°.

South of Bryce Creek where the fault crosses Bulldog Hollow, a low west-facing scarp a few feet high crosses the pediment surface. If this is a true fault scarp, it indicates some minor post-pediment, Pleistocene or possibly Holocene movement on this segment of the Paunsaugunt fault. A similar but less prominent scarp occurs where the fault trace crosses the pediment on Squaw Bench near the southeast corner of the map area. Holocene basalts are offset along the Sevier fault west of the Bryce Canyon area. According to Rowley and others (1981) the main phase of basin range type high-angle faulting in the southern High Plateaus probably occurred in late Miocene time, between 8 and 5 million years ago.

COMPRESSIONAL (LARAMIDE OR SEVIER TYPE) STRUCTURES

Evidence of compressional forces acting on the northern part of the Paunsaugunt Plateau has recently been brought to light by discovery of the east-west striking Rubys Inn thrust. This fault can be traced entirely across the plateau from the Sevier fault zone to the Paunsaugunt fault zone, a distance of about 12 mi. The structure was referred to as the Ahlstrom Hollow fault by Gregory (1951) and was thought to be a normal fault.

University of Arizona researchers under the direction of G.H. Davis recently discovered evidence of thrust faulting in the northern part of the Bryce Canyon region. Davis and Krantz (1986) noted the Rubys Inn (Ahlstrom Hollow) structure and evidence of thrusting in the Claron Formation cliff rocks as far south as Bryce Point. Detailed mapping of the geology within and north of the map area was done by Lundin (1987), who, supported by proprietary seismic evidence, confirmed the existence of post-Claron compressional deformation in the area.

The Rubys Inn structure shows southerly to southeasterly directed thrusting and vertical to overturned beds in Upper Cretaceous and Paleogene Claron rocks. The evidence for thrusting is most apparent in the cliffs just north of where Utah Highway 12 drops from the rim of the plateau and crosses the head of Tropic Canyon. There a double thrust with prominent striae and grooves on fault surfaces occurs within the pink member of the Claron Formation. Limestone beds in the lower part of the Claron have been repeated by thrusting in the cliffs above the highway.

Where the Rubys Inn fault crosses the highway, the double thrust merges into a single main fault. Just south of the highway, Cretaceous rocks have been thrust over vertical to overturned pink Claron. Farther westward the fault trace is covered by surficial deposits, but steeply dipping to overturned beds along the trend of the structure probably indicate proximity to the thrust. Lundin (1987) referred to these steeply dipping and overturned beds as fault propagation folds. Proprietary seismic data (Chevron, USA) indicates that the Rubys Inn fault is a ramp style thrust that soles out in the Carmel Formation and does not penetrate the underlying Navajo Sandstone. The Rubys Inn thrust dips northward at approximately 30°.

At the north edge of the map area, The Pine Hills form a line of north-dipping pink Claron rocks considered by Gregory to be in normal fault contact with Cretaceous rocks. Gregory (1951) mapped the largely alluvium covered Emery Valley as a horst of Cretaceous rocks between the Pine Hills and Ahlstrom Hollow (Rubys Inn) faults. Although the Pine Hills fault is not exposed at the surface, small-scale thrusts within the Claron of The Pine Hills (Lundin, 1987, p. 21) and seismic data indicate that the Pine Hills fault is a north-directed back thrust that dips southward at about 35° and is rooted in the north-dipping Rubys Inn thrust. Therefore the Emery Valley-Johnson Bench area is underlain by a compression wedge of Cretaceous rocks rather than the horst envisioned by Gregory. Lundin (1987, p. 22) estimated horizontal shortening of approximately 3,300 ft across the wedge.

North of the map area in Johns Valley, north and east of The Pine Hills, a second major thrust that is part of the Bryce Canyon thrust system has been revealed by seismic data and surface observations (Lundin, 1987, p. 27). The Johns Valley thrust strikes northeasterly and dips about 22° northwest, and like the Rubys Inn thrust soles out in the Carmel Formation. According to Lundin, the horizontal shortening across the Johns Valley thrust is greater than that on the Rubys Inn thrust and probably exceeds 4,900 ft.

The time of thrusting in the Bryce Canyon area is uncertain because the exact age of the pink and white members of the Claron, the youngest rocks known to be involved in the thrusting, is not known. The author favors an age of early to middle Eocene for the white Claron at Bryce Canyon. A tentative age of Oligocene is assigned the conglomerate at Boat Mesa, which does not appear to have been involved in the thrusts. If these age assignments are correct, it would place the time of thrusting between middle Eocene and Oligocene.Thrust faults in the Bryce Canyon region resemble in style the structures of the Sevier orogenic belt to the west. Sevier deformation in southern Utah is generally considered to have occurred in middle to Late Cretaceous time (Armstrong, 1968) and locally extended into the Paleocene (Stanley and Collinson, 1979; Rowley and others, 1979). The thrusts in the Bryce Canyon area seem to be too young to be true Sevier structures and differ in having a more southerly direction of transport than the easterly directed thrusts of the Sevier orogenic belt. Lundin (1987, p. 34) suggested the possibility that thrusting originated during Sevier orogeny and, following a period of erosion and deposition of the Claron Formation, the thrusts were reactivated during a younger south-directed compressional event. An interpretation of lithologs from shallow test holes drilled for coal in Johns Valley tends to support the idea of more than one episode of thrusting (E.R. Lundin, written commun., 1988).

PRE-CLARON STRUCTURES

It is clear that the the Bryce Canyon region was subjected to deformation and extensive erosion of Upper Cretaceous rocks before deposition of the Claron Formation. The Bryce Canyon anticline, a gentle northstriking fold first reported by Hager (1957), can be traced from Willis Creek northward to where it plunges beneath the cliffs of pink Claron at the head of Sheep Creek and Pasture Wash. On the crest of the anticline, all of the Wahweap Formation was removed by preClaron erosion, and the pink Claron was deposited directly on an erosion surface of low relief developed on the uppermost beds of the Straight Cliffs Formation.

Other evidence for pre-Claron deformation and erosion can be seen outside of the map area about 8 mi northeast of Bryce Canyon on the Johns Valley anticline, where a minimum of 2,500 ft of Upper Cretaceous rocks were removed from the crest of the anticline prior to the deposition of the Claron Formation.

THE BADLANDS

By John V. Bezy, U.S. National Park Service

Bryce Canyon is renowned as a masterpiece of erosional scenery. In past centuries, however, when man's principal concern was eking out a living from the wilderness, such rugged terrain inspired less exuberant descriptions. The name "badlands" (from mauvais terres) was first used by French fur trappers to describe eroded tracts on the northern Great Plainsa name later applied to Bryce Canyon and other highly gullied landscapes throughout the west.

Badlands the name will acquire special meaning after a hike through the column-filled amphitheaters of the park. Each amphitheater is a labyrinth of box canyons and sheer walls. Everywhere gullies have cut relatively soft limestone and shale of the Claron Formation into a maze of finlike ridges, narrow defiles, fluted columns, and pedestals. Shadowy, slot-like canyons offer escape from the heat and glare of unvegetated slopes, but not passage to the cooler plateau surface above. The pinnacled topography at Bryce Canyon is unduplicated in the Earth's other badlands. Landforms here are distinctive because of a very special combination of rock type, geographic position, and climate. The interaction of these factors, together with the interplay of weathering and erosion, is responsible for today's remarkable geologic statuary.

BEDROCK

The structure of the Claron Formation and its variation in thickness, chemistry, and texture make it a perfect medium for the sculpture of intricate badlands. Its sedimentary layers are characterized by a grid-work of horizontal bedding planes and by vertical cracks called joints. Weathering and erosion progress rapidly along these natural lines of weakness, etching out rectangular areas of bedrock that eventually form walls and pinnacles. Beds and joints largely determine the pattern, shape, and detail that the developing badlands will assume.

Bedding planes are planar or near planar surfaces that separate successive layers of stratified rocks from each other and represent surfaces upon which the original sediments were deposited. Bedding reflects changes in color, texture, composition, and rate of deposition of the sediments being deposited.

Joints are surfaces within the rock that are fractures, potential fractures, or partings without apparent displacement, as opposed to faults in which opposite sides of.the fracture have moved past each other. Joints commonly occur in vertical, or near-vertical, parallel groups called sets. The spacing and orientation of joints is controlled by rock type and nature of the Earth forces that have acted upon the rocks to produce them.

The weathering of joints leads to the decay of rock. Joints begin as minute cracks but are widened by weathering when exposed to the elements along cliff faces. Attack by weathering and erosion proceeds rapidly along the enlarging joints, cutting deep slots between ranks of pinnacles, as in Silent City, where features resemble the crumbling ruins of a deserted town.

A complex system of master joints (trending N. 33° W. and N. 21° E.), together with several minor joint systems, are significant structural features of the Claron Formation in the amphitheaters. These fractures occur throughout the formation and are probably the result of strain generated by large-scale crustal movements. Release of pressure by the erosional removal of overlying sediments may be a contributing factor in the production of joints.

Differences in the hardness of the various rock layers are also important. The individual beds of the Claron Formation, because of deposition in a fluctuating lake and fluvial environment, differ in thickness, chemistry, and particle size. Some of the more massive layers consist of freshwater limestone and dolomite both chemical precipitates high in calcium carbonate. Other strata are composed of silt and clay particles weakly cemented by differing amounts of calcium carbonate. The more firmly cemented a bed is, the greater is its hardness and resistance to erosion. Alternating beds of carbonate-rich and carbonate-poor rocks give the walls of Bryce Canyon their characteristic horizontal grooves and protrusions.

Massive beds of limestone and dolomite erode slowly under southern Utah's dry climate. These more resistant layers normally form protective caprocks that shield softer underlying beds from the elements. This selective sculpture of hard and soft layers, termed differential erosion, accounts for the detailed nature of the landscape.

GEOGRAPHIC POSITION

Exposure of the Claron Formation along the edge of the Paunsaugunt Plateau guarantees its dissection by gullies, for it is here that the full energy of running water is unleashed against the soft bedrock. Gullies draining the escarpment drop as much as 700 ft per mile, maximizing the velocity and erosive effect of flow down their channels. It is this intense headward erosion of gullies that carves large amphitheaters from the rim of the plateau.

CLIMATE

Climate exerts a tremendous influence on the formation of badlands. During summer, thunderstorms sweep over the plateau, delivering localized but intense showers. Because there is little or no vegetation to protect the steeper slopes from such downpours, and because the high clay content of slope material and bedrock prevents deep moisture penetration, most rainwater escapes down-slope in rivulets that cut the land surface with innumerable gullies. During these torrents, rock waste that has accumulated on bare slopes is flushed down drainages to the canyons below. Intense scouring accompanies the movement of this flood-borne debris through the canyons, cutting the floors deeper and deeper into the surrounding rock.

During winter, frontal storms regularly blanket the plateau with deep snow. On south-facing slopes, where the sun's direct rays can heat rock surfaces to nearly 60 °F, water from snowmelt percolates deep into bedrock along joints and cracks. When night temperatures drop below zero, the water within these fractures freezes, expands in volume by 10 percent, and exerts tremendous pressure (about 2,000 pounds per square inch) on surrounding walls. The force of expansion is directed against adjacent rock, prying and splitting it into angular fragments. This process is repeated over 200 times each year at Bryce Canyon and is extremely important in the shattering and disintegration of solid rock. North-facing slopes are in shadow and under snow for long periods and do not experience as many freezethaw cycles. As a consequence, frost wedging is less significant on these slopes.

WEATHERING AND EROSION

Weathering is an important prelude to erosion, breaking down bedrock and preparing it for eventual removal by running water. Bedding planes and joints provide channels that permit water, acid-bearing solutions, and plant roots to penetrate the rock. Beds of once solid rock are completely shattered by the growth of roots, and by frost wedging. Dislodged fragments creep in mass or fall down-slope, accumulating temporarily as slope debris and talus cones at the base of steep gullies. Chemical weathering is an equally important process, and its effects are beautifully expressed in form and color. Shallow alcoves, called grottos, are common in cliffs immediately below the rim, particularly west of Bryce Point. These cavities occur where seeping groundwater corrodes poorly cemented sandstone and other weak zones within the surrounding limestone caprock. Water circulating through the sandstone dissolves the calcium carbonate cement from individual grains, causing the rock to crumble to sand. This process of solution and sapping expands these recesses back into the walls of the escarpment. Continued deepening leads to roof collapse, with part of the old ceilings commonly left standing as natural bridges.

Another type of chemical decay is the oxidation of minerals. The Pink Cliffs weather to their various shades of red due to the alteration of small quantities of iron-bearing minerals found throughout the rock. When these microscopic iron particles combine with oxygen from air or groundwater, they rust, or oxidize, producing a red colored compound called hematite. Limonite, formed by the addition of water, produces a yellow tint. Traces of manganese oxide stain the walls blue, purple, and lavender. White indicates nearly pure beds of limestone and dolomite. The natural blending of these various hues creates almost the entire color spectrum. Yet, regrettably, most walls at Bryce Canyon are coated with a thin layer of reddish-brown clay, a "natural stucco" that conceals the colors of the underlying rock.

All along the Pink Cliffs, headward-eroding gullies are wearing back the rim. Estimates of the rate of escarpment retreat vary from 50 to 65 years per foot. Exposed roots of trees growing at the brink of the cliffs testify to the rapid erosion here. As small drainages wear back the edge of the plateau, resistant beds of limestone, dolomite, or sandstone are continually being exposed. As softer beds are washed away, these harder layers remain as prominent ledges and cliffs that project from the general slope of the escarpment.

As gullies cut down through soft clays into the more resistant beds below, they encounter the dense network of joints that permeates these rocks. Gully courses soon become entrenched along paths controlled by fractures. In fact, most streams draining the park's amphitheaters are guided by joint systems for a large part of their extent. Over thousands of centuries these drainages have sliced through the Claron beds, carving deep, narrow gorges such as Wall Street. Separating these canyons are long, thin ridges that are capped by erosion resistant beds that protect underlying strata. These knifelike divides extend from the edge of the plateau, fill the amphitheaters of the park, and give the Bryce Canyon badlands their unique character. Some fascinating patterns are produced by peculiar orientations of walls and canyons. In some areas, particularly below the rim of Boat Mesa, ridges occur in radial clusters-like spokes of a wheel. In other locations, secondary walls give the larger ridges a dendritic pattern, similar to veins in a leaf.

Canyon walls exhibit some striking features. Weathering has etched out and accentuated the differences between hard and soft rock producing the grooved and shelved structure of the walls. High on the canyon walls are diagonal lines that mark former levels of the canyon floor. These parallel scars, called "scour marks," are currently forming along margins of present canyon floors as water saps at the basal parts of adjacent walls. Graceful dripstone, resembling melted candle wax, decorates many of the walls. This "natural stucco" consists of a thin layer of clay washed down over wall surfaces by rain.

The continued weathering of soft beds gives rise to windows and arches in the long, narrow walls. Hollows and niches on opposite sides of the ridges enlarge, deepen, and finally join, riddling the walls with a line of "sky holes," as at the Wall of Windows. These openings generally develop beneath a hard caprock layer that prolongs their existence. Solution, rainwash, and gravity fall of rock fragments eventually enlarge arches and windows to the point where they can no longer support the weight of the protective caprock above. When the spans across the openings collapse, a serrated ridge crest consisting of isolated spires and pinnacles is created. Each of these upstanding features is capped by a block of old caprock, which, for a time, shelters the fragile column below from pelting rains. Each column becomes increasingly separated from its neighbors as weathering widens the intervening joint spaces.

Rainfall and differential weathering continue to modify jagged ridge tops, carving from their crests a multitude of bizarre pillars, pedestals, and toadstool forms that are collectively called hoodoos. Some of these features, depending on the viewers position and imagination, resemble famous persons and manmade structures giving rise to such names as Queen Victoria, Tower Bridge, the Chinese Wall, the Pope, and the Temple of Osiris.

By geological standards, all the features of Bryce Canyon National Park are short lived. Ultimately, their crowning slabs of caprock topple and expose the softer strata below to the direct impact of rain. In a relatively short time, many of these erosional features are reduced to low, conical hills that typify the Dakota Badlands and Arizona's Painted Desert. Thus the beautiful erosional forms of Bryce Canyon are continually being destroyed. But as the columns and other features disappear, new walls begin to emerge from the retreating edge of the plateau. As long as the Paunsaugunt Plateau exists, winter frost wedging and summer rains will continue to sculpture the colorful Claron Formation into ever changing monuments to erosion.

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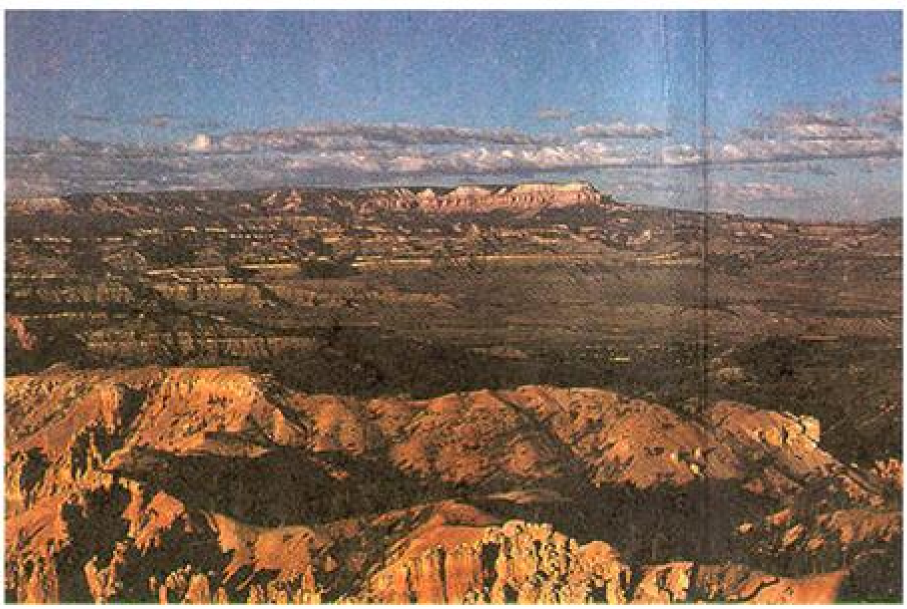
ANCILLARY INFORMATION

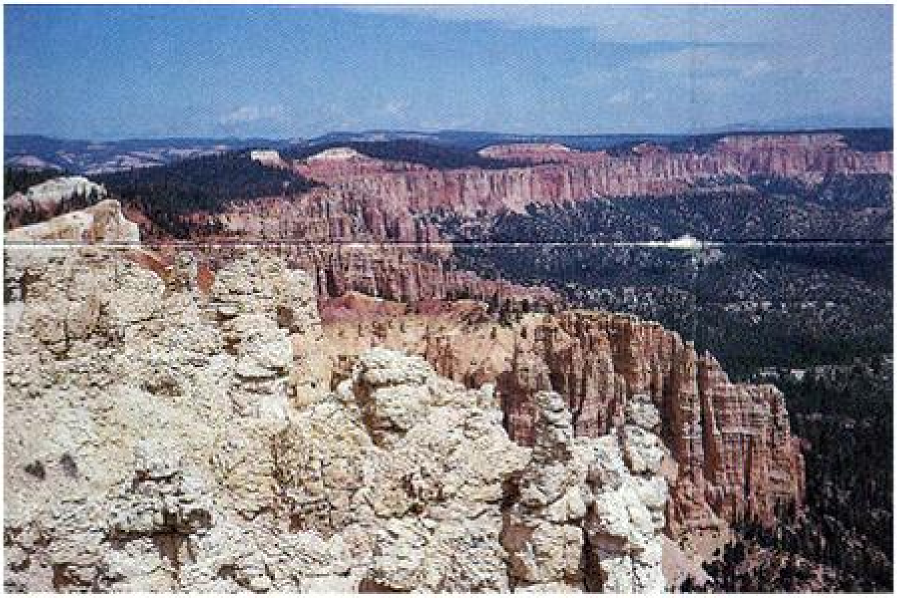
All photos from the Bowers, 1990 Report.

View north across Tropic
Canyon of Rubys Inn thrust fault. Continuous white limestone ledge above highway road cut marks base of thrust in pink limestone member of the Claron Formation.

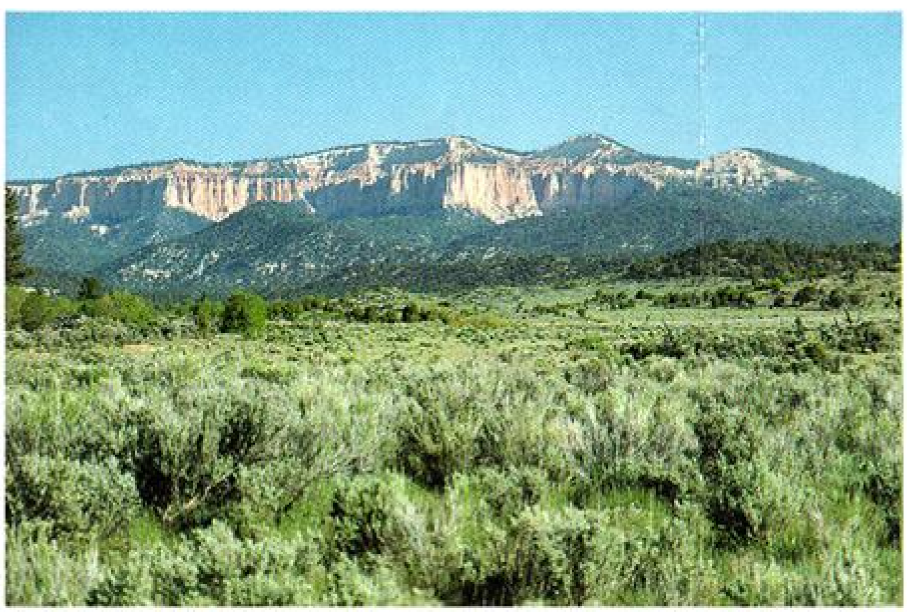
View east from Paunsaugunt Plateau across the Paria amphitheater.
Town of Tropic, Utah, in right center. Table Cliff Plateau on the horizon.



View northwest from Rainbow Point showing east face of Paunsaugunt Plateau.
White limestone member of the Claron Formation in foreground also caps distant buttes and overlies near-vertical cliffs of pink limestone member of the Claron Formation.

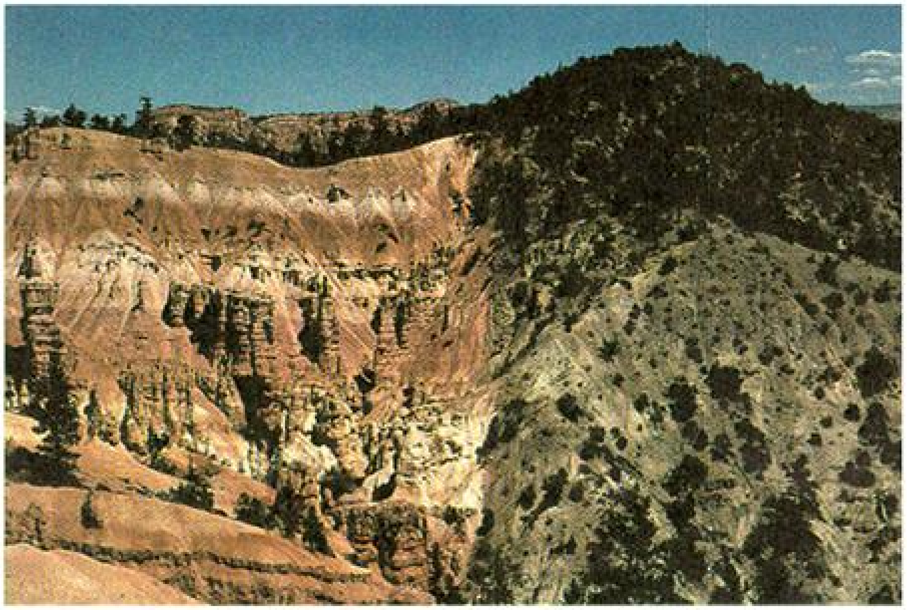


View north from Lower Podunk Creek of the Pink Cliffs at the south end of Bryce Canyon National Park.
Cap of white limestone member of the Claron Formation at Yovimpa Point lies on cliffs of pink limestone member of the Claron Formation. Drab-colored Upper Cretaceous rocks form tree-covered ridges below the Pink Cliffs.

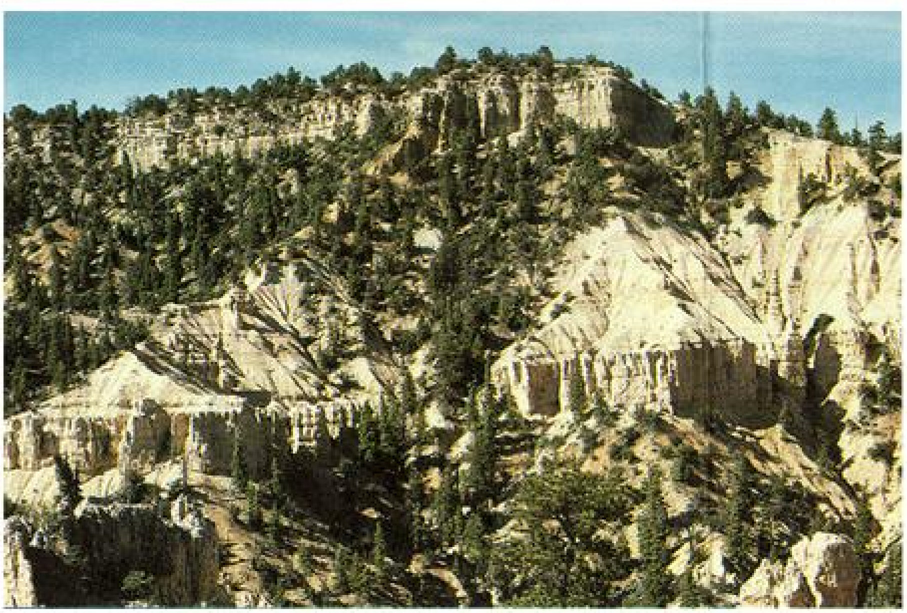


View north along strike of Paunsaugunt fault just north of Campbell Creek.

Beds of pink limestone member of the Claron Formation on left are faulted down against beds of the Upper Cretaceous Straight cliffs Formation. Vertical Displacement on fault is about 1,200 ft.



View of Boat Mesa along strike of near-vertical Fairyland fault.
Note offset of lower white limestone ledge in pink limestone member of the Claron Formation. Fault does not cut light-colored conglomeratic beds that cap the mesa



GRI Digital Data Credits

This document was developed and completed by Stephanie O'Meara (Colorado State University) from an earlier help file version developed and completed by Eileen Ernenwein (University of Denver) and Trista L. Thornberry (Colorado State University) for the NPS Geologic Resources Division (GRD) Geologic Resources Inventory(GRI) Program.

The information contained here was compiled to accompany the digital geologic-GIS map(s) and other digital data for Bryce Canyon National Park, Utah (BRCA) developed by Trista L.Thornberry and Stephanie O'Meara (Colorado State University).

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